Palmer, W. P. (2007) Diffusion of knowledge in Britain and America: some historical comparisons in science education between 1800 and 1920, at the 35th Annual Conference: International Co-operation through Education, ANZCIES (The Australian and New Zealand Comparative and International Education Society) at The University of Auckland, New Zealand from 30 November - 2 December. (non-refereed)

# DIFFUSION OF KNOWLEDGE IN BRITAIN AND AMERICA: SOME HISTORICAL COMPARISONS IN SCIENCE EDUCATION BETWEEN 1800 AND 1920.

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ABSTRACT
The aim of this paper is to consider some issues in the historical international development of science education making comparisons between the educational systems of Britain and the United States of America. The author's particular interest relates to the role of the textbook in science education, so this is area on which this study will concentrate.
Some issues for discussion are:
i. The transmission of scientific knowledge through textbooks both within and between Britain and America.
ii. Chemistry laboratory manuals, heurism and the practical teaching of chemistry in Britain and America.
iii. Gender issues in science textbook writing in Britain and America.
iv. Curricula in science education; the case of physiography.
v. Administrative issues and committee processes.
vi. Adult education and the public understanding of science.

These and other factors have had economic and other consequences far outside those that might have been anticipated.

**Conference details**
ANZCIES (The Australian and New Zealand Comparative and International Education Society)
35th Annual Conference: Theme: International Co-operation through Education
The University of Auckland, New Zealand
30 November - ANZCIES '07 conference commences
2 December - Conference closes
http://www.anzcies.org/call_for_papers.php

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## INTRODUCTION

This study attempts to give a broad-ranging picture of the influence of the science textbook over a little over a century in the development of Britain and America. There has been a rise in the standards of living of both countries and indeed in the whole of the developed world over the past two centuries. Economists from the 1960s onwards attribute much of this increase in individual wealth to improving standards of education. There are arguments about which is cause and which is effect, as there is some degree of symbiosis between rising educational standards and rising living standards. The study is not considering the desirability of increased standards of living as few who benefit from such improved outcomes see them as problematic.

The study also assumes that science education has played a major role in the process of development on the grounds that new technologies develop as scientific principles are applied in industry. The question then arises as to when science education started and how new scientific information was transferred from one generation to the next and attempts to make comparisons of science education between the United Kingdom (UK) and the United States of America (USA).

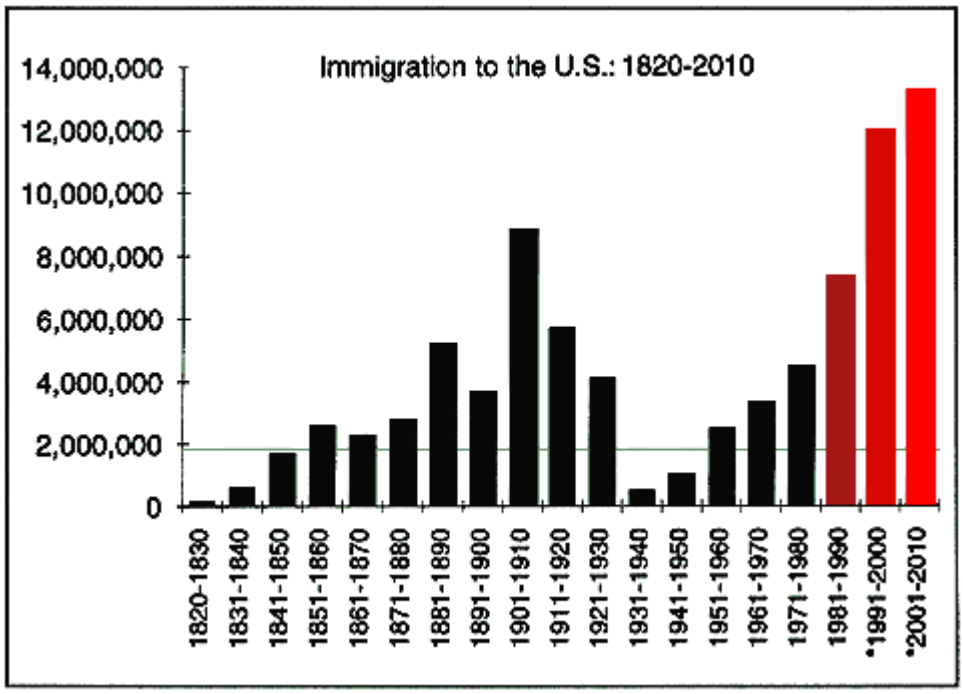
## THEORY AND RESEARCH

The aim of the paper is to relate some of the features of science education which the author of this study has noticed in his biographies of science textbook authors and scientists of the period differed considerably between the USA and the UK and to relate them to American scientific and technological success. Even if this connection could be established, the education of students in science would be one of a myriad of factors. Factors related to demography and the discovery of new resources would have been of major importance. Furthermore not all American practice was superior and there was a considerable degree of co-operation between scientists on either side of the Atlantic.

A very recent paper by Waks (2007, pp. 277–295) illustrates the problem well. Waks considers educational change and illustrates some of his arguments through a case study of the common school in the USA between 1830 and 1850 and he carefully explains that the changes may not be described empirically (p.13) but through careful analysis. Similarly this paper is considering educational change in two systems over an extended period of time, so discussion will be qualitative rather than quantitative.

Perhaps the only feature that may be easily observed quantitatively is the population increase in the USA (net immigration) indicating the tremendous pressure that

educational institutions were under over an extensive period of time. (The graph is taken from URL: Population Numbers, Projections, Graphs and Data). The population of the USA was 76,094,000 in 1900 and 106,461,000 by 1920 (URL: United States population): by comparison the US population in November 2007 was above 303 million people.




* Projections and graph courtesy Population Environment Balance. Sources: U.S. Census Bureau[2]; Statistical Yearbook[40], Bureau of Citizenship and Immigration Services
Average 195,000 per year from 1921-1970

For the United Kingdom, the population was smaller and the rate of growth much smaller as may be indicated by the following paragraph:

> We know that the UK population was roughly 22.3 million in 1851, 38.2 million in 1901, 50.2 million in 1951 over 59 million in 2001, and in mid-2005, 60.2 million, of which 50.4 million lived in England.
>
> (URL: United Kingdom population)

Social and political factors such as the American civil war, slavery, class in the UK, female emancipation, the world wars and the depression also had a huge effect on the teaching of science in both countries.

**EDUCATIONAL GROWTH IN BRITAIN AND THE USA: 1800-1920**

Science education in English secondary schools was virtually non-existent at the start of the nineteenth century (Turner, 1927, p. 87). The major traditional independent (public) schools were slow to introduce science to the curriculum with Rugby school being amongst the first in 1849 (ibid, p. 88). At some newer public schools, such as Mill Hill, science (Natural philosophy) was introduced in 1821 (ibid, p. 87). Universities introduced the sciences very much earlier with Cambridge having a Chair in Chemistry (Archer, &

Haley, 2005) as early as 1702. In primary schools, science was a late arrival to the curriculum. The earliest teaching methods in contemporary science lessons in primary schools were catechistical texts made up of questions and answers to be recited by students. There were texts that provided information for students through model conversations and finally there were object lessons where the teacher brought in objects relating to the area being learnt and the teacher asked questions about the subject. A number of articles such as Kerr (1999) provide general background to sources.

Sources for information about science education in the USA between 1800 and 1920 are plentiful but the following were of particular value. Firstly De Boer's book *A History of Ideas in Science Education: Implications for Practice* provides a good historical basis across the whole period. Articles by Kohlstedt, (1990), Heffron (1995), Barber (1916) and Powers & Blick (1945).

Myron Atkin & Black (2003) provided insights into the ways in which science education has developed historically in both the UK and the USA. They consider that in the nineteenth century, American public schooling was seen as a way of building shared values by a polyglot population through common schools to form a sense of nationhood. In Britain, schooling was supported by the fear that an uneducated lower class might be a source of widespread social unrest. Science education may well have less serious consequences but helped the rural populations in both the USA and Britain with the new industrial and technological consequences.

In addition a number of the author's papers will be utilized to provide specific background.

## VIEWS EXPRESSED ON SCIENCE EDCATION IN USA AND UK (1800-1920) WITH REGARD TO CLASSICAL EDUCATION

One feature common to both the USA and UK was the resistance of classicists to the introduction of science to the curriculum, though views to the contrary were also expressed.

> Herbert Spencer pointed out in 1860 that we study and revere science not simply to produce and encourage more scientists but also to make better parents, better church-goers, better citizens and workers, better students of art and culture no less than of physics, chemistry, or mathematics. (Heffron, 1995, p.181)

One feature of English education of the time was the large amount of time spent on classical education.

> A century ago when the cult of the classics probably reached its peak in England it was everywhere taken for granted in the boys' Public Schools, and to a somewhat lesser extent in the grammar schools, that at least one half and sometimes as much as two-thirds of the curriculum should be devoted to the grammar and literature of the dead languages. (Campbell, 1968, pp. 308-325)

Rev Tuckwell (UK) wrote a short pamphlet which was a plea with letters of support from a number of academics (p.3) where he stated that 'The claims of science to be regarded as a necessary element have been urged by every scientific man of eminence in the kingdom…' Tuckwell also asserts that the existing classical culture is so one-sided that science is disadvantaged in educational institutions. He raised questions about the age at which teaching science should start and about the content of the science curriculum.

H. G. Wells (1917, pp. 196-206), who was a well known author of popular fiction, berated the English educational system for its over-emphasis on classical education.

Sanderson (1917) who was the Headmaster of Oundle School and an early supporter of science education claimed that science teaching in schools is less effective than classical teaching as scientists appear as specialists and do not impart inspiration and idealism to their students.

> The classical master has always had charge of a form of boys, and he has made his influence felt in every part of their school life. He teaches classics, but he teaches much more than classics; from him the boys get their inspiration and ideals. (Quotation by Sanderson sourced as Anonymous, 1923)

A guide to science experiments used at Oundle School (Sanderson, 1917) was also provided. (pp. 207- 249) which shows that in spite of the above quotation Sanderson had also encouraged the teaching of science at Oundle.

Osborne summarises the general opposition to the inclusion of science in the curriculum, in spite of its influential supporters.

> However, even with its origin in the middle of the nineteenth century with influential champions such as Huxley and the then secretary for education, Lyon Playfair, both major proponents of such a view, there remained many who like Matthew Arnold felt that scientific training as a form of education would produce only 'useful specialists' and not a truly educated man. Scientific education in Victorian England was battling against the hegemony of the two Cs- Christianity and the Classic… .(Osborne, 2002, p. 38)

The nineteenth century saw the initial entry of science teaching into education in both Britain and America. From an American viewpoint, DeBoer (1991) claims in his first two chapters that scientific education came at the expense and in spite of the objections of the classical tradition (Gutek, 1992). Science education was justified as of practical value, relevant to modern life, and equally or better able than the classics to train students in logical reasoning, and judgment. In general the objections of the classicists to the teaching of science were less vehement in America than in Britain. There is one American case which was that of Gustavus Detlev Hinrichs of Iowa State University where a University Chief executive cut the budget of a successful science program so severely that it caused decades of wrangling (Palmer, 2007).

## VIEWS EXPRESSED ON SCIENCE EDCATION IN USA AND UK (1800-1920) WITH REGARD TO EXAMINATIONS IN SCIENCE

A feature of English education, which was common to most areas of the curriculum was a reliance on examinations at all levels of education. In America, examinations played a less significant role. The views of some critics of the role of examinations in science are included below.

Napier Shaw (1916, p.13) rails against the examination system with the telling critique 'An evil microbe has got hold of the teaching of physical science.' A little later he stated (pp. 13-14) 'I attribute the sawdust with which the examinations are stuffed to the prolonged examinations of the same type.'

H. E. Armstrong, well-known as a strong advocate of heurism, did not like payment on results or examinations and he and Professor Ayrton would not 'countenance examinations which reduce all to one dead level' (Armstrong, 1903, p. 135).

William Ramsay (1896) compared university courses in Britain and Germany and from his extensive experience he came to the conclusion that British courses were over-reliant on the examination system.( Ramsay, 1896)

Smith considered that 'the memory work and the absence of independent effort by the pupil, along with mechanical methods of teaching were what vitiated the former attempts to introduce science in schools.' (Smith, 1917)

However not all science educationalists were so completely against science education in the UK. Hodson, editor of an influential book *Broad lines in science teaching* summarised his views as follows:

> The heuristic method, which is commonly practiced in dealing with introductory science work, and which must give place, when the examination stage is reached, to a speedier method of accumulating information… . (Hodson, 1911, p. 92)

## THE TRANSMISSION OF SCIENTIFIC KNOWLEDGE THROUGH TEXTBOOKS

The word science is problematic in this context, but with regards to textbooks will include those for specific sciences, such as the physical sciences, the life sciences with geology and astronomy as well as general science. School textbooks in the Victorian era were most usually in physics, chemistry and biology, but include new topics or combinations of topics such as physiography.

The author of this study has built up a collection of science textbooks and other science education works through purchasing via Ebay and booksellers over a period of 20+ years. One very obvious feature is the number of American science texts for sale as compared with British texts. There are a variety of reasons for this, but it does seem in general that American students had to purchase their own textbooks, whereas in Britain the books were sometimes purchased by the school and were lent to the student for a year. After

five to ten years of student use these were usually worn out and discarded. If this is largely true, there would have been two economic consequences. Firstly it would account for there being fewer British science texts available for sale now. Secondly the American market for textbooks would have been much larger than the British market over a long period of time. This would have encouraged a greater variety of authors with new ideas constantly emerging. In broad terms, this fits in with the observations of the author of this study. Finally there would have been more incentive for American students to take care of and preserve the books that they had purchased. Some examples of British and American science textbook authors will be mentioned. If science textbooks (mainly considering chemistry texts) over the period 1800 to 1920 were considered in terms of educational merit, the vast majority in the author's view would be American.

Early in this period in Britain Jane Marcet (Palmer, 2003. pp. 98-99) and Jeremiah Joyce (Palmer, 2003. p. 103) stand out as science writers of elementary science texts. In America, perhaps Benjamin Silliman Senior (Palmer, 2003. p. pp. 99-100), John Lee Comstock (Palmer, 2003. p. 101) and Almira Phelps (Palmer, 2003. p. pp. 99-100). Jane Marcet's chemistry text is said to have initially interested the young Michael Faraday in chemistry, when he was delivering books as a bookbinder's apprentice. Her book *Conversations on chemistry* was widely plagiarized in America by a number of authors including Comstock. Jeremiah Joyce's books stayed in print for the best part of a century. Silliman was appointed as a Professor of chemistry with no knowledge of the subject. Comstock wrote textbooks in several of the sciences and his books remain easily available secondhand today. Almira Phelps was an experienced teacher and made excellent practical suggestions. Elliott (1979) summed up Phelps' contribution as follows:

> As an educator, she helped to make more widespread the study of science by girls while texts promoted acceptance of science as part of the American school curriculum. (Elliott, 1979, p. 204)

British text book writers tended to write books at the university level whilst many American text book writers wrote at secondary level. One American writer of texts for primary school students (Mary Amelia Swift) wrote her first book in 1833 with pictures, prayers and large print so that it appealed to young children. In fact, it was so popular that it was translated into Burmese and Karen by missionaries and later used by the Japanese in their technological revolution of the 1870s (Palmer, 2007b).

Three textbooks authors who were particularly influential educationally will be mentioned as case studies.

The role of Edward Livingston Youmans (1821-1887) was especially significant in American Science Education. Youmans' claim to greatness in the sphere of science education lies in the textbooks he wrote for children, the beautiful coloured illustrations that he produced (even though he was only partially-sighted) to explain the chemical concepts of his time, his extensive international educational contacts and his editorship of

*Popular Science Monthly;* all of these increased the public's understanding of science (Palmer, 2005a).

In 1977, David Layton (1977a: 1977b: 1977c) asked the question 'Which five men can be considered the founding fathers of science education in Britain?' One of the colourful characters that he mentioned was Professor Pepper of 'Pepper's ghost' fame. Pepper may be little known to science students or teachers today and he deserves to be better known, because of his exciting experiments which incorporated elements of showmanship and magic. He wrote a number of beautifully produced books, which were inspirational to a number of students who later claimed these books had encouraged them to study science. His most memorable experiment was called Pepper's ghost. He spent most of the latter part of his life working in Australia (Palmer, 2005b).

Joel Dorman Steele was born in Lima, New York, on 25 May, 1836. During the American Civil War, he was appointed Captain but was severely wounded early in the war. His recovery took a long while, but eventually he returned to teaching. Later he became Principal of a run-down school in New York, where he was respected as a first-rate teacher because instead of using standard texts, he used his own carefully prepared notes. The notes eventually became the source material for his books, which usually had the generic title *Fourteen weeks in* followed by the name of the subject. His books were immediately popular. He claimed no originality but he said that his contribution was 'simple interesting language'. The books contain many diagrams and evidently, seven of Steele's books were still in print in 1928. Steele's later years were dogged by ill-health and he died aged fifty in 1886.

**LABORATORY MANUALS, HEURISM AND STUDENT PRACTICAL WORK**

The author of this study has researched American laboratory manuals for the last ten years and has a large collection of laboratory manuals (Palmer, 2006b: 2006c). American laboratory manuals (chemistry) generally were the property of an individual student for a year. They contain the experiments to be carried out printed on the left hand side of the page, whilst the right hand side of the page is left blank and the student wrote his/her results there. There appears to be no similar manuals in Britain. It may be that British students did equal amounts of practical work but in a format that has been destroyed, but the probability is that American students in chemistry actually did the experimental work that heurists like H. E. Armstrong so strongly promoted.

The first American laboratory manuals that the author has found were produced by Gustavus Detlef Hinrichs in the early 1870s. The books (*The elements of physics* and *The elements of chemistry and mineralogy*) (Hinrichs, 1870: 1871) warrant further description. They defined the experiments that the students actually carried out practically. Hinrichs had two assistants when the course prospered, making it very much like a modern tutorial system. Both books were printed by a local publisher (Griggs, Watson, & Day). Hinrichs' advice to teachers is excellent:

> 498 The teacher should give his personal attention to each student—make regular rounds passing from one to the other. He should carefully notice everything the

> student does—commend what deserves commendation, and carefully correct errors in handling apparatus, in writing, in calculation, etc. Only if the teacher is thoroughly at home in the work, will he be able to do as required, and instruct with profit. It will be seen, how different this mode of instruction is from the popular "hearing a recitation". (Hinrichs, 1870, p. 162)

Later versions of laboratory manuals changed considerably since Hinrichs' prototype: some outstanding features of American laboratory manuals are:

i.) Huge numbers are still available for sale via the internet about a century after their publication. This may indicate the widespread nature of practical science in America over a long period of time. In this author's view this has been a major positive influence on science education in the USA.

ii.) The contents of American laboratory manuals move from the elementary to the advanced and for those students who completed the course, the breadth of the coverage, particularly of inorganic chemistry is extensive. Many experiments would be considered hazardous with modern safety advice.

iii.) Many of the named books that the author has obtained were of female students. Indeed in one book there was an old handwritten class list with half the class being female. This indicates that American science classes of the early twentieth century were probably more balanced in terms of gender than comparable British science classes

**SOCIAL ISSUES IN SCIENCE EDUCATION**

In terms of gender, American science education was (as stated above) more evenly gender-balanced than in Britain. Both Britain and America produced increasing numbers of scientists as the twentieth century progressed. It is interesting to note that only fifteen British women chemists mentioned in *The Oxford Dictionary of National Biography*, which contains biographies of 514 British male chemists (Kauffman, 2004) amongst the total of 50,000 biographies. No comparable American data is available, but females would be expected to have played a larger part in American science.

British science education had class barriers to overcome that were not equally present in America. In the case of Britain, Gowing comments about the class barriers found in 1870:

> What of science education around 1870? There was hardly secondary education outside the private sector which was dominated by the so-called public schools and endowed schools and in most of these science education was negligible. (Gowing, 1978, p.5)

In the case of America for example, as early as 1818, Emma Willard was urging the New York legislature to provide support for female education (Beadie, 1993, p. 543).

Racial discrimination has been the difficulty in America with very unequal resources put into the education of blacks and whites, with the Civil War, largely about the issue of slavery taking place between 1861 and 1865. Nonetheless there were some positive stories in the teaching of science. Here is a description of a successful man of colour in

1896, who through hard work became a regular professor of natural science. The extract indicates that he used laboratory manuals for his students in physics and chemistry.

> His position has grown upon him and he has grown in the position, so that now he is regular professor of Natural Science, and temporarily of Latin. Through his energy and industry the school has a good working chemical laboratory and a fair set of physical apparatus. Physics is taught mainly by experiment, chemistry almost entirely so. The only books used in the latter branch are a Laboratory Manual and the students own notebook
>
> (A missionary in the south, 1896, p. 322)

## PHYSIOGRAPHY IN BRITAIN AND THE USA

Physiography was started as a combination of geography and general science introduced by Huxley in England in 1869; the details are related below by Krapotkin (1893):

> When Professor Huxley introduced, twenty-three years ago, the name and the subject of Physiography, his intentions were certainly excellent. Natural sciences were almost entirely excluded at that time from the schools. The teaching of geography stood very low: … Under the name of Physiography natural sciences were, so to say, smuggled into the schools. And by showing how the study of Nature may be approached, and methods of scientific observation may be rendered familiar by examining things close at hand, Professor Huxley has undoubtedly rendered an immense service to this country. He has brought about a far-reaching reform. However, the very form which physiography assumed in his well-known textbook, and especially later on in schools, shows that the reform was not thorough enough.
>
> (Krapotkin, 1893, p. 350)

Over time the subject died in the United Kingdom becoming general science and the meaning of the word physiography in the United States changed slowly, so that it now only refers to the physical geography usually of a limited area. There is nothing of particular significance about this except that the details of the changes though the different textbooks produced in Britain and America make an interesting comparative study.

## THE PUBLIC UNDERSTANDING OF SCIENCE

The public understanding of science is an area where educationalists in both Britain and America often feel that they have been insufficiently active. Questions such as ‘Why is it that the majority of Americans look upon science as something beyond the understanding of the average citizen? (Wilson, 1952, p. 148) are asked in both Britain and America. There has certainly been a diffusion of views between scientists on either side of the Atlantic over a long period of time. In America many individuals from early in the nineteenth century spent time and energy as traveling lecturers and received appreciative attention from the general public. As early as 1817, Amos Eaton was giving lectures in chemistry, geology and botany (Warner, 1978, p. 63); he kept this up daily for twenty

four years until the year before his death (Palmer, 2003, p. 101). Silliman senior took to the road in the 1830s giving numerous public lectures (Warner, 1978, p. 63).

In England Faraday (Faraday, 1861) gave his public lectures for children at Christmas each year and this tradition has continued until the present day. In England from about 1871 a group of well-known scientists including Huxley, Roscoe, Wilkins, Odling and Carpenter gave a series of lectures at Manchester Town Hall Anon (1871).

Perhaps the other method of diffusion of knowledge of science is by the provision of cheap books. In England Sir Allan Lane of Penguin Books helped to provide inexpensive books on all subjects to the general public. In the USA, a publisher named Emanuel Haldeman-Julius, brought out very cheap publications called Little Blue Books, just stapled together (saddle stitched) which eventually sold at just five cents each. Quite a number of his Little Blue Books related to science, particularly to evolution which he supported. These publications were snapped by the poor of America and many people who are now famous owe their education to these little books which would fit in a shirt pocket (Palmer, 2006d)

**CONCLUSION**

These are some of the differences between science education as provided in the USA as compared with those of the United Kingdom. Although there is much that is similar between the two countries, there are features of the US education that are superior to the British system. Perhaps some credit needs to be given to American science education for American economic success.

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